Feeding Habits and Structure of the Gut of the Australian Freshwater Prawn *Paratya australiensis* Kemp (Crustacea, Caridea, Atyidae)

PREM GEMMELL

GEMMELL, P. Feeding habits and structure of the gut of the Australian freshwater prawn *Paratya australiensis* Kemp (Crustacea, Caridea, Atyidae). *Proc. Linn. Soc. N.S.W.* 103 (4), (1978) 1979: 209-216.

A study of the feeding habits and histological details of the alimentary canal of *Paratya australiensis* is presented. Functional morphology and histology of the various regions of the gut are described and discussed in relation to food and feeding habits.

Prem Gemmell, School of Anatomy, University of New South Wales, Kensington, Australia 2033; *revised manuscript received 27 March 1978, accepted 20 September 1978.*

INTRODUCTION

Alimentary adaptations in decapod crustaceans have attracted the attention of workers since the beginning of the century. Parker (1876), Calman (1909), Yonge (1924), and Patwardhan (1934, 1935) were pioneers in the field. Recently George *et al.* (1955), Fryer (1960), Schaefer (1970) and Powell (1974) have contributed considerably to the study of decapod alimentary organization.

Paratya australiensis (Kemp) is a common freshwater small prawn that favours vegetated areas. It occurs in a wide variety of permanent inland waters (coastal streams, rivers, lakes, farm dams and ponds). Williams (1977) described its occurrence in south-eastern South Australia, south-western New South Wales extending northwards into Queensland. The present investigation is the first study of the alimentary adaptations of this species in relation to its feeding habits.

MATERIALS AND METHODS

Specimens of *Paratya australiensis* were collected monthly from Manly Dam, N.S.W., during the period October 1972 to February 1973. The specimens were brought to the laboratory alive and were kept at a constant temperature of 18°C for further observations. For histological studies specimens were fixed in alcoholic Bouin's fluid for 24 hours. The antennules, antenna, thoracic and abdominal appendages were cut right to the base and the carapace was completely removed to allow easy penetration of the fixative. The fixed material was subsequently washed, dehydrated, embedded in paraffin (M.P. 56°C) and sectioned at 6 μm. The sections were stained in Delafield haematoxylin and eosin and mounted in D.P.X. mounting medium.

OBERVATIONS

FEEDING HABITS

Paratya australiensis is a browser and filter feeder. During browsing the food is collected by chelipeds. The food which consists of fine particles and insects is scraped off the substratum by the strong toothed spines. As the fingers of the chela approach the substratum, they open widely; on contact with the substratum the terminal spines and setae become splayed out. As the chela closes and begins to be withdrawn its setae come together; their elasticity ensures that the extremities are held closely to the substratum and a considerable area is scraped. The scraped material is held by the opposed sets of setae. The serrated edges of the toothed spines of chela are responsible for scraping the substratum and loosening the detritus. Larger particles are picked up by the combed, and the finer ones by the brush setae. The loaded spines then pass into the mouth parts where the grid setae of the first maxilliped strip off the food. The chelipeds are also used for breaking down the larger particles of food.

During filter feeding, *Paratya* holds itself in a slanting position near the surface of the tank. Strong water currents are produced by the metachronal beatings of the endites of the first maxilla and scaphognathite of the second maxilla, these appendages are fringed with long dorsally directed setae which pass the food in the midventral line towards the mouth. The direction of food currents during this action is firstly towards the animal from the sides and secondly, from behind forwards along the mid-ventral line. Small particles of food suspended in water are taken up by the toothed and plumose setae on the inner side of the endites of the first and second maxillipeds. The stout spinous setae of the first maxilla help in scraping off the food from the setae of the more posterior appendages. The food is passed into the buccal cavity via the mandibles.

Fig. 1. T.S. through the oesophagus of *Paratya australiensis* showing the disposition of the oesophageal folds. C = chitin, C.M.F. = circular muscle fibres, D.F. = dorsal fold, EP. = epithelium, L.M.F. = long muscle fibres, M = mouth, MAN. = mandible, OES. = oesophagus, SM. = submucosa. Magnification: approx. x90.

Fig. 2. T.S. through mouth, oesophagus and the cardiac proventriculus showing the cardio-oesophageal junction. C = chitin, C.OES.O = cardio-oesophageal orifice, C.PROV. = cardiac proventriculus, D.F. = dorsal fold, L.F. = lateral fold, P.PROV. = pyloric proventriculus, S = seta. Magnification: approx. x90.

Structure of the Gut

The alimentary canal of *Paratya australiensis* consists of a foregut, midgut and hindgut.

FOREGUT

The foregut includes the mouth, oesophagus and the tventriculus. The mouth (M′) is ventral between the two mandibles. In front the labrum overlaps the mouth and the incisor processes of the mandibles.

The oesophagus (Fig. 1) is a narrow tube ascending from the mouth and opening into the cardiac proventriculus. The cardiac end of the oesophagus is dilated and thrown into three folds — one dorsal and two lateral (D.F. and L.F.). The wall of the oesophagus is lined internally by chitin, columnar epithelium, thick submucosa of loose connective tissue, circular and longitudinal muscle layers and an external layer of connective tissue.

The proventriculus (Fig. 2) is divided into an anterior large cardiac proventriculus (C.PROV.) and a posterior small pyloric proventriculus (P.PROV.). The two are separated by a prominent depression.

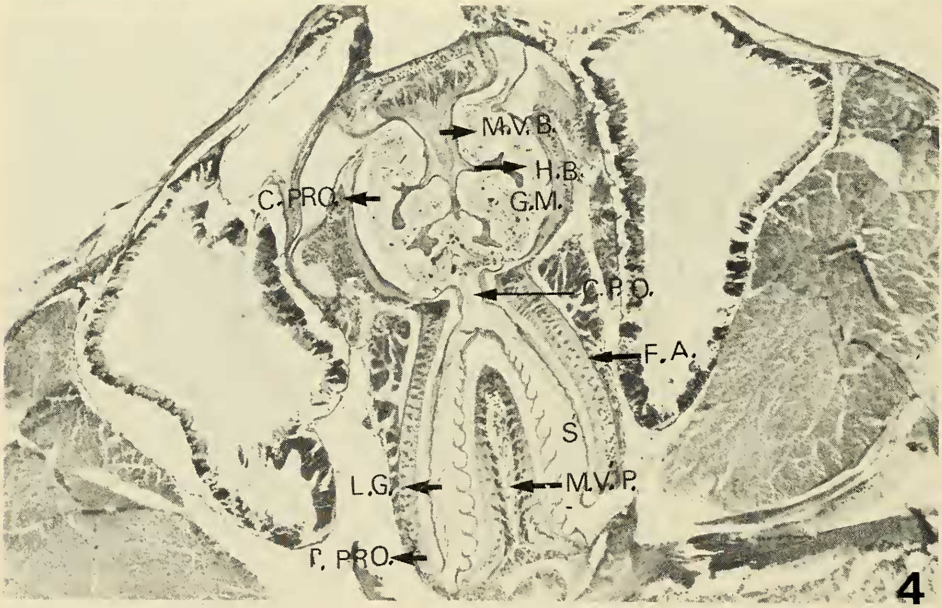
The cardiac proventriculus is a dilated pouch in which food can be accumulated. Regurgitation of food from the cardiac chamber into the oesophagus is prevented by the oesophageal folds (D.F. and L.F.) at the termination of the oesophagus. The cuticular lining (C.) of the cardiac proventriculus constitutes a setose gastric mill (G.M.)

The cardiac proventriculus in *Paratya* shows a median vertical bar (M.V.B.) extending from the anterior to nearly the posterior end of the chamber. Two pairs of short horizontal bars (H.B.) attached to its sides are covered with chitin (C.). The lateral bars show serrated edges on both sides; probably to increase the triturating surface. The chitinous lining (C.) of the cardiac proventriculus is produced into long fine setae (S.) which are inwardly and downwardly directed (Fig. 2).

The chitinous lining of the pyloric proventriculus is produced into a number of setae (S.) forming the filter apparatus (Figs 3 and 4). From the base of the pyloric proventriculus arises a median ventral piece (M.V.P.) that extends up to the anterior end dividing the pyloric proventriculus into two narrow lateral grooves (L.G.); one on either side of the median piece. The chitinous lining of the pyloric proventriculus is produced into a number of spines (S.) all along its lateral edges. The spines are inwardly and upwardly directed, becoming progressively smaller from the base to the apex. The lateral edges of the median ventral piece (M.V.P.) are similarly produced into small groups of spines at regular intervals. The spines are large at the base, becoming smaller towards the apex. The larger spines overlap the smaller ones in front of them producing a many-pocketed sieve-like structure. Between the two sets of spines, that is the ones along the lateral lining of the pyloric chamber and those on the median ventral piece is a narrow space — the lateral groove (L.G.) which ultimately releases fine food particles into the midgut (M.G.) (Fig. 5). The coarse particles are retained for further action. This observation is supported by the presence of large food particles in the cardiac and fine in the pyloric proventriculus.

The pyloric filter apparatus of *Paratya* is continued into the midgut in the form of chitinous pyloric sheath (P.S.). The sheath collects coarser food particles from the filter apparatus and prevents it from mixing with fine food particles. The pyloric sheath (P.S.) in *Paratya* consists of only two semicircular chitinous folds lying opposite each other lateromedially and slightly overlapping at the sides.

The epithelium lining the proventriculus is tall columnar, supported by a thin basement membrane (B.M.); a submucosa of loose connective tissue, circular muscle fibres and a peripheral layer of loose connective tissue.



Figs 3 & 4. T.S. through the proventriculus showing details of the gastric mill, filter apparatus and the disposition of the digestive glands. B.M. = basement membrane, C. = chitin, C.M.F. = circular muscle fibres, C. PROV. = cardiac proventriculus, C.P.O. = cardiopyloric orifice, EP. = epithelium, F.A. = filter apparatus, G.M. = gastric mill, H.B. = horizontal bar, INT. C. = intestinal caeca, L.G. = lateral groove, M.V.B. = median vertical bar, M.V.P. = median ventral piece, S = spine, SM. = submucosa. Magnification: approx. x110.

MIDGUT

The midgut (Figs 5 and 6) is a short tube. Two long diverticulae — the intestinal caecae (INT.C.) arise from its anterior end and extend on either side of the proventriculus. The midgut is lined by columnar epithelium supported by a thin layer of loose connective tissue, an inner layer of circular muscle fibres and an outer layer of longitudinal muscle fibres followed by a thin investing sheath.

HINDGUT

The hindgut is short and narrow. The inner surface is thrown into a number of broad folds (Fig. 7). The wall consists of the following layers — an inner layer of columnar epithelium covered by chitin, submucosa of loose connective tissue, inner layer of circular (C.M.F.), outer layer of longitudinal muscle fibres (L.M.F.) and a thin limiting membrane.

Digestive Glands

The digestive glands are complex greenish-yellow tubular structures occupying most of the cephalothorax. The lobules of the glands are arranged around a lobular duct. These ducts join together to form the main duct that opens into the midgut. The lumen is lined by tall columnar secretory cells that are highly vacuolated, the resting cells showing a number of granules in the cytoplasm. The epithelium is supported by connective tissue and smooth muscles which encourage the discharge from the secretory units.

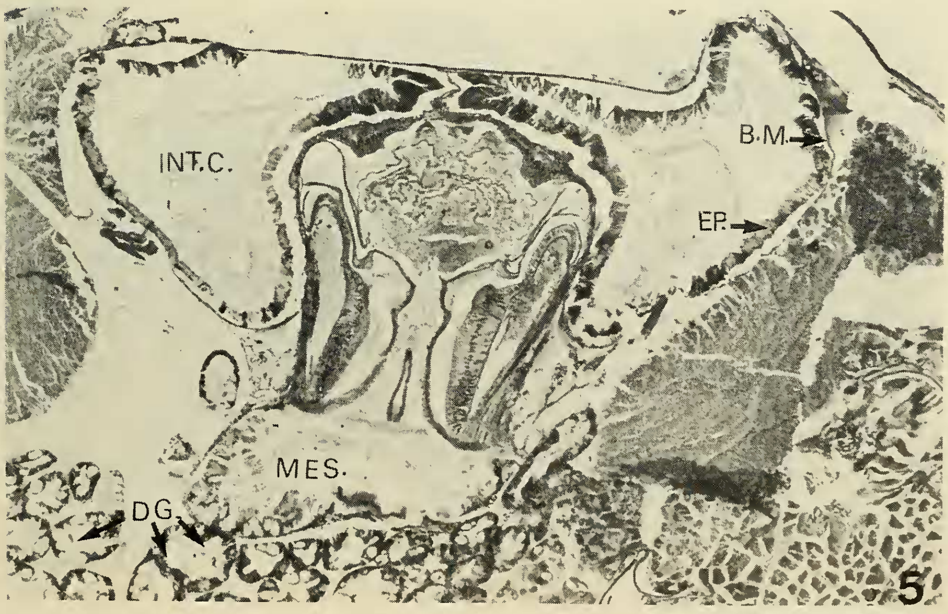


Fig. 5. T.S. through the proventriculus and the mesenteron showing the opening of the filter apparatus into the mesenteron. B.M. = basement membrane, DG. = digestive glands, EP. = epithelium, INT. C. = intestinal caeca, MES. = mesenteron. Magnification: approx. x110.

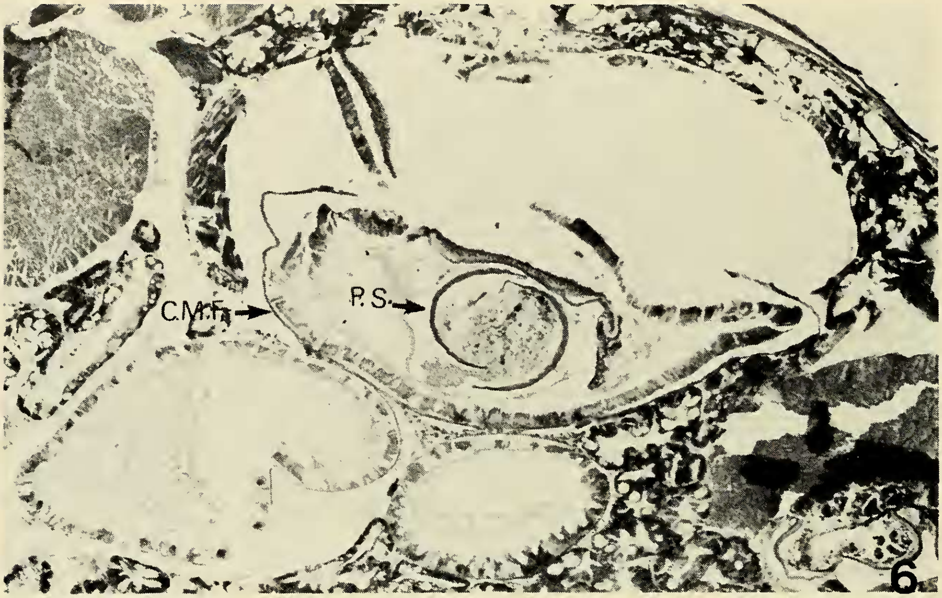


Fig. 6. T.S. through the mesenteron showing the position of the pyloric sheath. C.M.F. = circular muscle fibres, P.S. = pyloric sheath. Magnification: approx. x110.

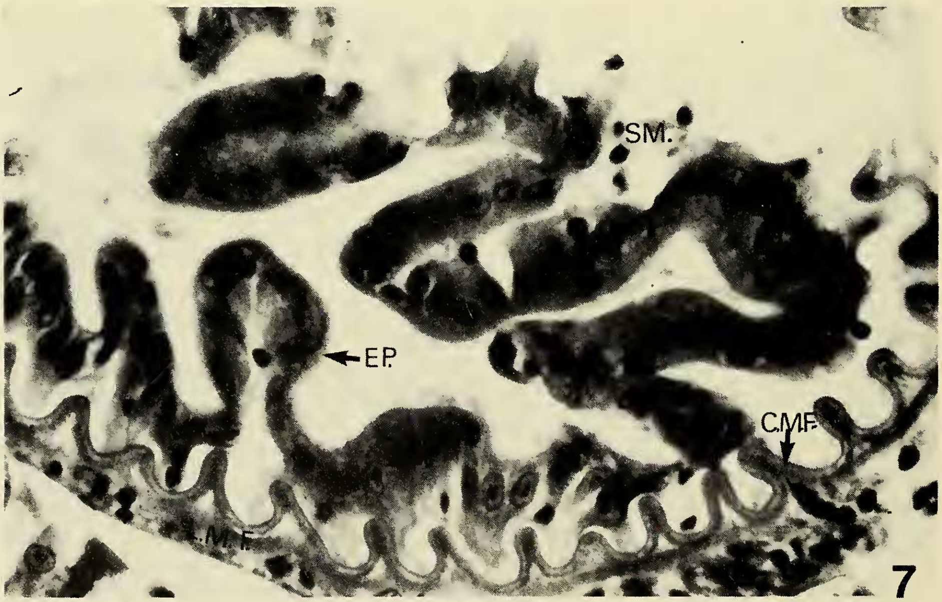


Fig. 7. T.S. through the proctodaeum. C.M.F. = circular muscle fibres, EP. = epithelium, L.M.F. = longitudinal muscle fibres, SM. = submucosa. Magnification: approx. x250.

Discussion

The maxillae in *Paratya australiensis* are adapted for producing water currents. The endites of the first maxilla and the scaphognathite of the second maxilla along with the maxillipeds produce strong water currents. Smaller particles of food are picked up by the thickly arranged setae on these appendages and passed to the mouth. The chelipeds are used for picking up larger particles of food, breaking it into bits and their final transference to the mouth. The chelipeds are also responsible for scraping, collecting the detritus and its transfer to the mouth. The present investigations are in accord witth the finds of Fryer (1960) on *Caridina africana* and *C. nilotica* and Kotpal (1971) on *Penaeus lamarrei*.

The morphology and histology of the gut give ample evidence of the structural modifications of the gut to suit its food and mode of feeding. *Paratya* is seen to feed continuously for long intervals. The presence of a distensible oesophagus permits these quantities of food to be swallowed at a time. The oesophageal folds prevent regurgitation of food. Similar observations have been recorded in *Panulirus* (George *et al.*, 1955), *Metapenaeus bennettae* (Dall, 1967) and *Callianassa* (Powell, 1974).

The stomach of crustaceans has been described as the gastric mill by various authors, for instance Parker (1876), Huxley (1880), Patwardhan (1935), Reddy (1935), George *et al.* (1955) and Schaefer (1970).

Review of the literature reveals in every case the stomach is differentiated into two regions, the anterior masticatory portion — the gastric mill — and a posterior pyloric portion — the filter apparatus. The size, shape and the structure of the gastric mill is variable in different groups. A strong gastric armature as identified by the presence of large calcified ossicles is mainly dependent on the size of the animal and the hard nature of the diet of shelled molluscs and arthropods. Though the word gastric mill is used by all the workers for its masticatory function the details given are highly variable.

Paratya australiensis is a small freshwater prawn feeding primarily on aquatic plants, algae, diatoms and insects. In association with the soft nature of the diet, and well-developed mandibles, the gastric mill in *Paratya* does not show any calcified ossicles as described by Huxley (1880), Patwardhan (1935) and Reddy (1935). The filter apparatus in the pyloric proventriculus is mainly used for sieving finer particles of food before they enter the midgut for digestion. The details of the filter apparatus show a strong resemblance to those observed in *Caridina laevis* (Pillai, 1960), *Corophium volutator* and *Caprella linearis* (Aggarwal, 1963, 1964), *Metapenaeus bennettae* (Dall, 1967) and *Callianassa* (Powell, 1974). The pyloric brushes described by Powell were, however, absent in *Paratya*.

The pyloric sheath in the mesenteron is a simple structure in *Paratya* and is functionally comparable to the terminal lappets of *Penaeus setiferous* (Young, 1959) and pyloric fingers of *Callianassa* (Powell, 1974).

Microscopic studies of the gut wall of *Paratya* show an inner layer of circular muscle fibres and an outer layer of longitudinal muscle fibres which are contrary to the observations of George *et al.* (1955) in *Panulirus,* and Vonk (1960) in *Astacus*. Pillai (1960) and Dall (1969), however, observed the arrangement of muscle fibres in the gut wall of *Caridina laevis* and *Metapenaeus bennettae* to be similar to that of *Paratya*.

The digestive glands open into the mesenteron, which is the site for digestion and absorption of food. Intestinal caeca showing identical histological details to that of mesenteron can be inferred to perform similar functions. The present investigations are in agreement with the findings of George *et al.* (1955), Aggarwal (1963, 1964) Dall (1967) and Powell (1974).

ACKNOWLEDGEMENTS

I thank Professor D. T. Anderson, School of Biological Sciences, University of Sydney, Sydney, for his help in the preparation of this manuscript. My sincere thanks are due to Dr G. C. B. Poore, Senior Research Officer, Marine Studies Group, Victoria, for his helpful criticism of the manuscript.

References

AGGARWAL, V. P., 1963. — Functional morphology of the stomach of *Corophium volutator*. *J. Linn. Soc.* (Zool.), 45, No. 303: 47-52.

——, 1964. — Functional morphology of the stomach of *Caprella linearis* (L.). *Current Science,* No. 20: 618-619.

CALMAN, W. T., 1909. — *Crustacea.* In Lankester's *Treatise on Zoology,* Vol. 7. London: Adam and Charles Black.

DALL, W., 1967. — The functional anatomy of the digestive tract of a shrimp *Metapenaeus bennettae* Racek and Dall. *Aust. J. Zool.,* 15: 699-714.

FRYER, G., 1960. — The feeding mechanism of some atyid prawns of the genus *Caridina. Trans. R. Soc. Edinb.,* 64: 217-244.

GEORGE, C. J., RUBEN, N. and MUTHI, R. T., 1955. — The digestive system of *Panulirus polyphagus* (Herbst). *J. Anim. Morph. and Phys.,* 2: 14-27.

HUXLEY, T. H., 1880. — *The crayfish, an introduction to the study of Zoology.* London: Kegan Paul, Trench, Trubner and Co., Ltd.

KOTPAL, R. L., 1971. — *Arthropoda.* Meerut: Rastogi and Company Educational Publishers.

PARKER, T. J., 1876. — On the stomach of freshwater crayfish. *J. Anat. Physiol.,* 11: 54-60.

PATWARDHAN, S. S., 1934. — On the structure of the gastric mill in decapoda. *Proc. Indian Acad. Sci.* B, 1: 359-375.

——, 1935. — The structure of the gastric mill in reptantons Macrura — Caridea. *Proc. Indian Acad. Sci.* B 1: 414-422.

PILLAI, S. R., 1960. — Studies on the shrimp *Caridina laevis* (Hellee). *J. Mar. biol. Ass.* India. 1 (1): 57-74.

POWELL, R. R., 1974. — The functional morphology of the foreguts of the thalassinid crustaceans, *Callianassa californiensis* and *Upogebia pugettensis. Univ. California Publ. Zoology,* 102: 1-47.

REDDY, A. R., 1935. — The structure, mechanism and development of the gastric armature in stomatopoda with a discussion as to its evolution in Decapoda. *Proc. Indian Acad. Sci.,* B1, 10: 650-675.

SCHAEFER, N., 1970. — The functional morphology of the foregut of three species of decapod crustacea *Cyclograpsus punctatus* Milne Edwards, *Diogenes brevirostris* Stimpson and *Upogebia africana* Ortman. *Zool. Africana,* 5 (2): 309-326.

VONK, H. J., 1960. — Digestion and Metabolism [in] *The Physiology of Crustacea,* Vol. I. New York and London: Academic Press.

WILLIAMS, W. D., 1977. — Some aspects of the ecology of *Paratya australiensis* (Crustacea, Decapoda: Atyidae). *Aust. J. Mar. Freshwater Res.,* 28: 403-415.

YONGE, C. M., 1924. — Studies on the comparative physiology of digestion. II. Mechanism of feeding, digestion and assimilation in *Nephros norvegicus. J. Exp. Biol.,* 1: 343-389.

YOUNG, J. M., 1959. — Morphology of the white shrimp, *Penaeus setiferous* (Linnaeus 1758). *Fish. Bull. U.S. Fish and Wildlife Service* 59 (145): 1-168.